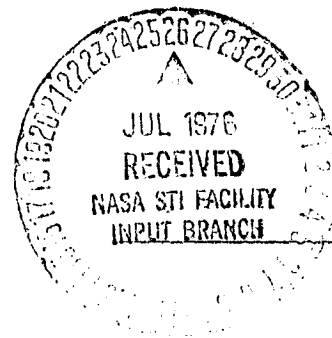


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J. Morisset

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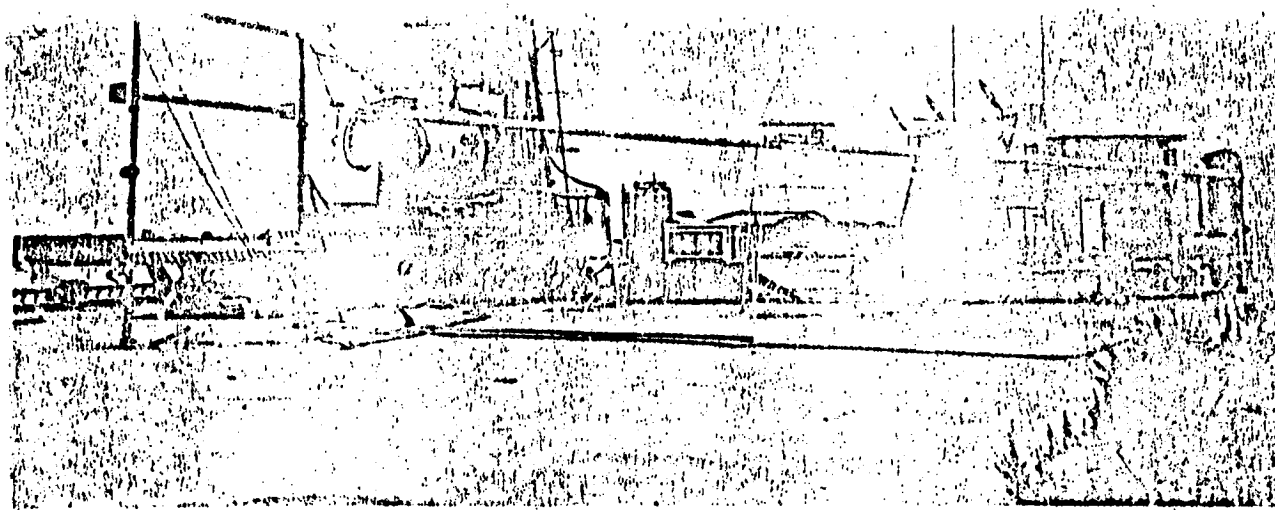
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16. Abstract Development of the CFM-56 bypass turbojet engine is well into the test-bench phase, with 1000 test hours clocked in 18 months. The design offers advantages of high bypass ratio and an advanced core engine comprising a single-stage blower and compressor. Performance data on the core-engine components, with over 6000 test hours, are give. The test program is well ahead of schedule and results are satisfactory. Foreign body ingestion tests, aerodynamic noise tests, and crosswind and tailwind performance tests have been completed.					
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THE CFM-56: BALANCE SHEET OF 18 MONTHS OF TESTING

J. Morisset

Eighteen months ago, the CFM-56 turbojet development program /*23 entered the test-bench phase. The four engines produced thus far recently clocked 1,000 test hours. 1976 will see the introduction of more of these engines, and their creators, General Electric and SNECMA, have great expectations for the model. The time is fast approaching when important decisions reaching beyond the initial development phase will have to be made. So, it is time to pause and take stock of this joint French-American program, which has proven to be precedent-setting in a number of ways.



The CFM-56-002 at the SNECMA environmental testing center at Istres (bench RM 3).

One Engine for Three Families of Aircraft

First, a recap of the CFM-56: It is a dual-flow, high-bypass-ratio turbojet designed specially for the new generation of short

* Numbers in the margin indicate pagination in the foreign text.

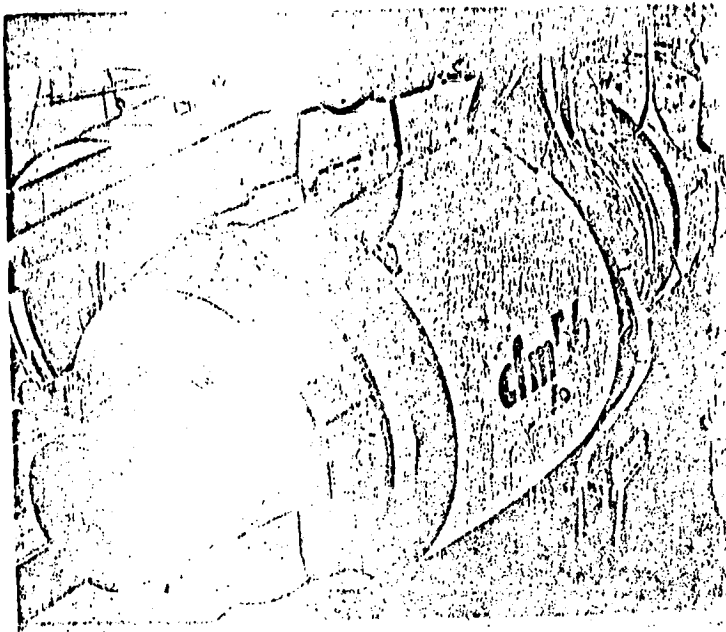
and medium-range planes and long-haul aircraft for low-density routes. The former will be twin or tri-engine planes, and the latter will be four-engine, but a preliminary market study has shown that the same 10-to-12-ton-thrust engine is perfectly suited to all these craft, as well as to planes derived from current models and those that require re-engining to extend their service life; this is not to mention military aircraft such as the AWACS, the YC-15's and the future successor to the "Transail," which may even further expand an already vast market.

The stakes are thus enormous for both General Electric and SNECMA and their associates. Thousands of CFM-56's will be built, and the model's promoters estimate that their new engine will span the next two decades. At the moment there is only one potential competitor, the JT10D¹; it should be borne in mind that the CFM-56 already has more than a year's head start in its development, and that this edge will tend to become more and more pronounced as tests progress, at a rate far above that of the JT10D.

The CFM-56 is, of course, based on the most advanced technologies, but it enjoys a number of special advantages as well: cooperation between G.E. and SNECMA is very solidly defined and is being developed in an ideal atmosphere, due not only to the determination of the engineering teams to produce the finest possible engine, but also to an equal determination on the part of management in both companies to make a success of production and marketing operations². The CFM-56 could well be the first example of truly efficient and successful collaboration between the two countries in an area of major importance.

¹The JT10D is being developed at present by Pratt and Whitney with a relatively minor participation of M.T.U.; Fiat is also involved, but Rolls-Royce official participation in the program is expected imminently.

²It should be remembered that the CFM-56 program is managed by the French-chartered CFM International, created on a 50-50 basis by SNECMA and G.E., which acts as a single customer interface in matters of sales and after-sales.



The CFM under test at SNECMA's bench 1 C.7 at Melun-Villaroche.

Experience

The CFM-56 enjoys another special advantage: the core engine, i.e., the gas generator (hot part) of the engine is directly derived from that of another sophisticated engine, G.E.'s F-101 (the engine of the B-1), and thus benefits from the experience already gained by that engine (more than 6,000 hours), the development of which has involved a sizeable investment.

In the case of the CFM-56, this is an excellent guarantee. /24
SNECMA's contribution to the CFM-56 is the valuable experience gained in the last few years in the areas of fans and transonic compressors: SNECMA has developed, after many mockup tests, a fan + LP compressor system that not only gives high performance, but also has several special advantages such as the absence of "fins" between the blades, and the peripheral "stubs," allowing better performance and good mechanical response.

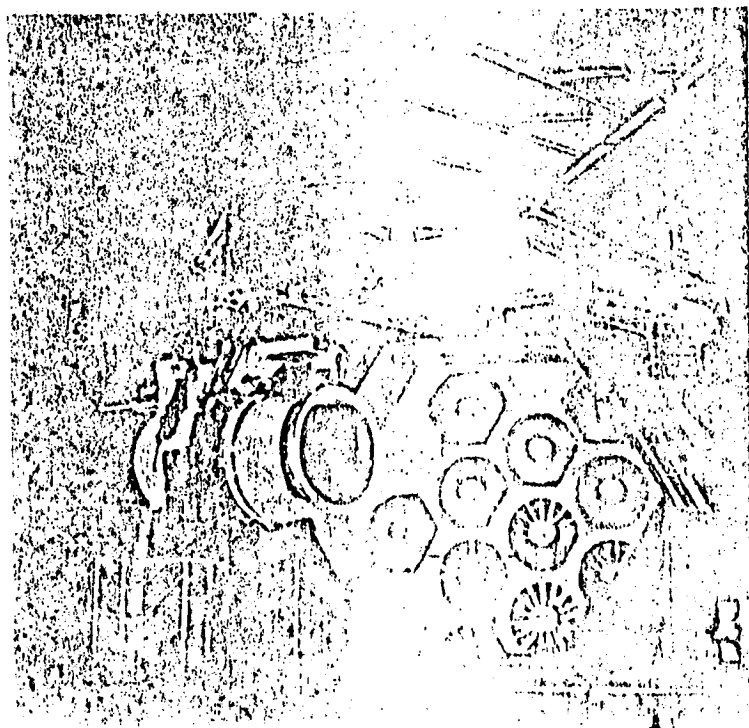
Basic Features

Before reporting on the program, we should review the basic features of the CFM-56.

The single-stage fan, specially designed to achieve a low noise level, is about 1.80 meters in diameter; both the disc and blades are made of titanium alloy; its components are forged by SNECMA

at Gennevilliers (the production parts are "forge finished"). Its simple design makes it possible to individually replace each blade without touching the rest of the engine. Also to be noted is the cone-shape of the nose (adopted after tests at C.E.Pr.), which reduces the risk of ice accumulation. The fan rotates in a stainless steel housing made at the Gennevilliers rolling mill.

The pressure ratio of this fan is 1.6 and its flow is 400 kg/sec.



Crosswind tests at Peebles.

The LP compressor is 3-stage and also made of titanium alloy; there are four sets of stator blades; bleed valves similar to those of the CF6-50, are slaved to the control system of the adjustable stator vanes of the HP compressor; they enable the LP compressor to function properly in all modes, including reduced mode or rapid deceleration (generous stall margin).

The bypass ratio of this LP system is nearly 6, and the outlet pressure ratio of the LP compressor reaches 2.6.

Next comes the core engine, furnished by G.E., which is comprised of:

- a nine-stage HP compressor (as compared to 14 in the CF6-50) with four sets of adjustable stator vanes.

- a very short combustion chamber, which means savings in terms of the length of the engine, its weight, and the pollution level (the formation of nitrogen oxides depends on the time spent in the chamber); water injection may thus be eliminated.
- a single-stage HP turbine, cooled, but with an operating temperature lower than that of the CF6-50.

Behind the HP turbine, which is the end of the General Electric core engine, there is a four-stage LP turbine; the vanes are cast (lost wax process); the four nozzles are designed in sections of 3 and 6 vanes (also cast), which means a reduction in manufacturing costs and in improvement in performance by reducing leaks. The LP compressor is linked to the LP turbine by means of a shaft which is forged and then extruded (only the exterior is machined).

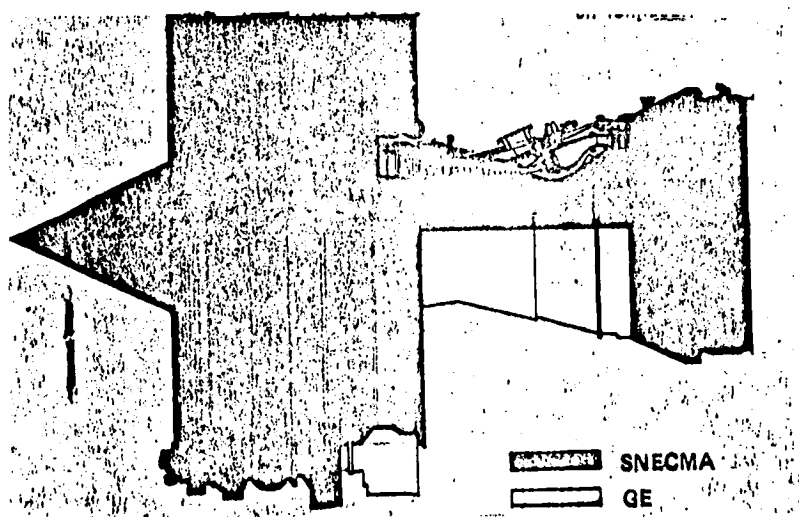


The fan blades may be removed and replaced individually; note the absence of the "fin" and the "stub" at the tip of the blade.

Between the two compressors is the power take-off shaft (driven by the HP compressor) of the accessory gearbox. This shaft rotates at 18/19,000 rpm and can transmit 500 kW. The accessory gearbox, developed by Hispano, was first bench-tested, and then tested on the engine as of last May. This gearbox carries the fuel pump, the lubrication module (developed by F.N.), the air starter having a force of 100 hp (Garrett type on the engine during tests) and the IDC (60 kVA generator).

The turbine housing, externally cooled by air duct rings, and the exhaust housing, also of refractory alloy (mechanically welded) should also be mentioned.

The control system of the CFM-56, developed by G.E., is similar to that of the CF6: it is a hydro-mechanical system, acting on fuel flow and the setting of the first sets of guide vanes of the HP unit; however, the hydro-mechanical control mechanism is supplemented by an electronic system, the PMC (power management control), which modulates the control and acts as a trim, providing a constant N.1 for a given throttle position. The PMC, which will also be installed on the CF6-50 L, is used, for example, to limit take-off thrust (flat rating).



Schematic section of the CFM-56; the compactness of the engine is remarkable, particularly in its length.

This system is /25 particularly important for transient conditions, since it limits temperature increases by bringing them from approximately 20°C (in 100 to 200 seconds) to 7 or 8°C; this means added service life for the more sensitive components.

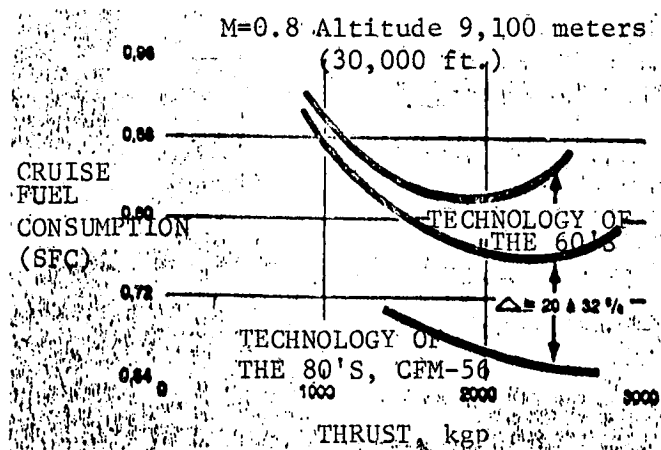
The entire engine is remarkably compact, and is supported by only 5 bearings. It is attached by only two frames to the aircraft, one at the front and one at the rear (exhaust housing).

Its length (front flange to rear flange) is 2.28 meters and its maximum diameter (front flange) is 1.81 meters. Total weight: 1,750 kg.

The LP equipment rotates at 4,500/4,700 rpm, and the Hp equipment rotates at about 14,000 rpm.

Performance

Take-off thrust (conditions ISA + 15°C) is reported at 22,000 pounds, and will be increased to 24,000 pounds in about two years of use, without changing engine specifications. Other development stages are anticipated, bringing it up to 25,000 pounds.



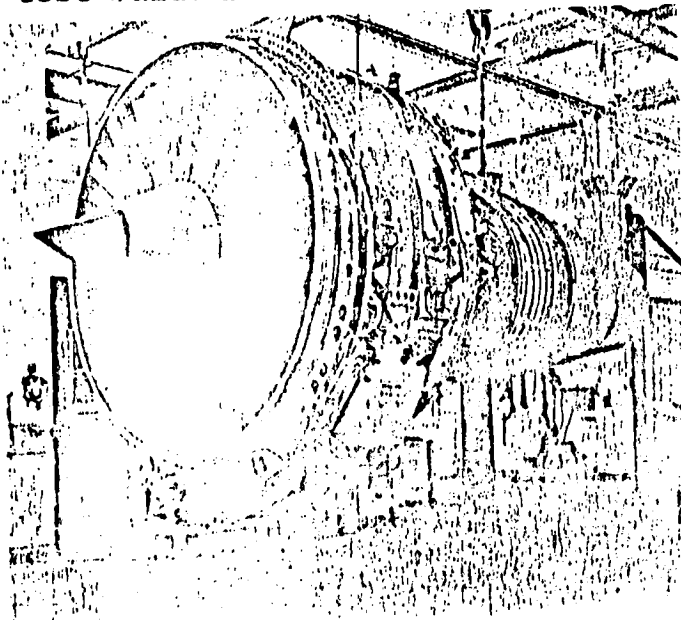
Comparative graph of the uninstalled engine; the transition from classic technology to a technology of the 1980's provides a savings of 20 to 32% in specific fuel consumption (SFC), (Mach 08 and 30,000 feet).



This recent photo of the CFM-56-002 shows the final accessory gearbox; the first engines began their tests with a temporary gearbox borrowed from another engine; the present engines are much less "instrumented" than at the time of the first tests, but the attached sensors still enable measurement of several hundred test values.



The CFM-56 accessory gearbox, developed by the Hispano-Suiza division, supports both "engine" and "aircraft" accessories.



Overall view of the CFM-56 at Melun-Villaroche.